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PRELIMINARY RESULTS OF THE MEASUREMENT OF THE WATER CONTENT OF THE MARTIAN ATMOSPHERE MADE BY THE MARS-3 AUTOMATIC INTERPLANETARY STATION

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Translation of "Predvaritel'niye rezul'taty izmereniy soderzhaniya H_2O v atmosfere Marsa na avtomaticheskoy mezhplanetnoy stantsii Mars-3," Doklady Akademii Nauk SSSR, Vol. 208, No. 4, 1972, pp. 45-48

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16. Abstract IR absorption, incl. cts. spectra, was done in the 1.38 micron band. This is better than U.S. Iris system, which uses 25-50 micron, because atmospheric T profile is not a factor. Since the expected equiv. width of the key band is small, interference-polarization (modulation) can be used. The phase detected signal was calibrated to give equiv. width of the 1.3827 mu line, and a power function (Farmer, Porte) related this preliminarily to P and moisture density in the subsatellite column. Lower instrumental limit is 0.5 x 10^{-4} cm^{-2} (precision is ±0.3 x 10^{-4} cm^{-2}); real moisture is 0.1-25 x 10^{-4} cm^{-2} (usually under 8 x 10^{-4} cm^{-2}). Equatorial dust clouds caused low readings on one date; dark continents could lower readings by 50%; and polar caps were site of lowest. Dec.-Feb. low readings explain a drop in hydrogen corona density compared to Mariners 6 and 7. A plot of brightness temperature is also given.

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PRELIMINARY RESULTS OF THE MEASUREMENT OF THE WATER CONTENT OF THE MARTIAN ATMOSPERE MADE BY THE MARS-3 AUTOMATIC INTERPLANETARY STATION

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F. A. Korolev, and V. C. Zhegulev
(Submitted by Academician G. I. Netrovym on 28 June 1972)

The Mars-2 and Mars-3 automatic interplanetary stations (AIS) (scientific Mars satellites) are equipped with IV-2 [Moisture Meter 2] instruments, designed for measuring the water vapor content in the planetary atmosphere. Such measurements have the following important advantages compared to observations from the earth [1-7]: /45

1) the measurements are carried out at closer range (1000--1500 km at the pericenter of the orbit), and the spatial resolution is around 5-10 km, which is two orders of magnitude better than from the earth;

2) all the difficulties connected with telluric absorption have been completely removed, and smaller amounts of H_2O can be observed than from the earth.

The IV-2 instrument (Fig. 1) measures the H_2O content in the Martian atmosphere from the absorption in the center of the 1.38 micron band. The $\lambda = 1.38$ micron band for H_2O is formed in the spectrum of reflected solar radiation, and its equivalent width is practically independent of the vertical temperature distribution in the planetary atmosphere. This constitutes the principal difference between the IV-2 and the Iris instrument used for the same purpose in the American Mariner-9 station [8]. Iris records the rotational band of H_2O in the region 25-50 micron, the intensity of which depends

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* Numbers in the margin indicate pagination in the foreign text.

so strongly on the vertical temperature distribution that the band can be observed both in absorption and in emission [9].

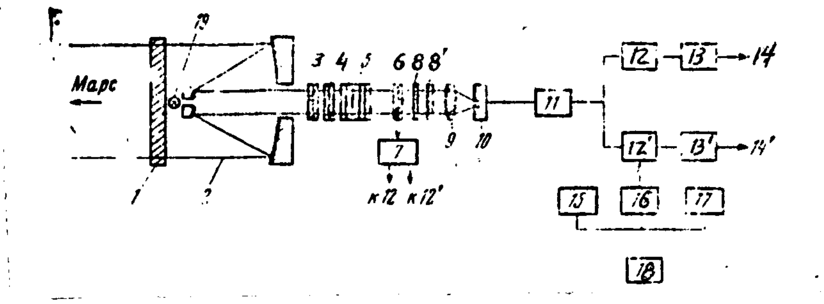

Fig. 1. Optical diagram and electrical block diagram of IV-2 instrument: 1 -- hermetic window; 2 -- cassegrainian telescope; 3 -- interference filter; 4 -- fixed polaroid filter; 5 -- birefringent crystal; 6. rotating polaroid filter; 7 -- sensor of the reduction of the polaroid filter (6); 8 -- Si filter; 8' -- ADP [ammonium dihydrogen phosphate] filter; 9 -- Fabry lens; 10 -- PbS photoconductor; 11 -- preliminary amplifier; 12, 12' -- phase detectors; 13, 13' -- dc amplifier; 14, 14' -- telemetry outputs; 15 -- regulator of rotational rate of polaroid filter; 16 -- voltage converter; 17 -- crystal temperature stabilization circuit; 18 -- on-board power supply; 19 -- test lamp.

Since the expected equivalent width of even the strongest lines in the center of the 1.38 micron band in the Martian spectrum is small, a modulation method is used for measuring it. An interference-polarization filter, consisting of a plate of Iceland spar (a birefringent crystal 5) and two polaroid [filters] (4, 6), and the interference filter 3, separate the three lines in the center of the band: 13788, 13807, and 13827 Å. With the rotation of the polaroid filter 6, the transmission maxima of the interference-polarization filter alternate periodically with minima, and the intensity at the output of the instrument in the presence of absorption lines is modulated. The amplitude of the modulated component of the signal depends upon the energy absorbed in the lines. The optical scheme and the electronic block diagram of the photometer are given in Fig. 1; the objective is a cassegrainian with diameter 80 mm, relative aperture 1:20, and angular field of vision 0.005 radians (6 km at a range of 1500 km); the light receptor is a PbS photoconductor.

The fixed polaroid filter 4 is oriented toward the main axis of the birefringent crystal 5 at an angle differing a little from 45°. As a result, a second modulated component appears, the amplitude of which is determined, in general, by the continuous spectrum. Its phase is inherently shifted by 90° relative to the first, and the associated electrical signals can be easily resolved by the phase detectors 12 and 12'. Two voltages are measured at the output of the instrument; their ratio depends on the equivalent width of the absorption lines. To check the operation of the instrument in flight there is a test lamp 19, which is switched on for several /46 minutes before the optical axis intersects the limb of the planet, and [again] after it passes through the terminator.

The instrument is calibrated in the laboratory with the aid of a lamp with frosted glass, the signals from which are measured at different distances from the instrument. The moisture in the room is controlled. A coefficient of proportionality was found between the ratio of the output voltages n and the equivalent width W of the 13827 Å line. For this line the relation was calculated between the intensity and the amount of water vapor u in the sight path, for pressure p = 13 mbar, and with spreading by CO_2 molecules, in [10]. We extrapolated these data to the Martian atmosphere, assuming that the latter consists of pure CO_2, that the effective pressure is 3 mbar (half the surface pressure), and that the equivalent width /47 obeys the law

$$W \propto u^{0.5} p^{0.3}, \qquad (1)$$

found in [11] for all the bands in general.

The calibration curve thus obtained is provisional, and will be made more accurate by further calculations and laboratory measurements. The lower limit of water vapor content which can be observed by the IV-2 instrument is around 0.5 μ of precipitated water in the line of sight. The amount of water vapor in a vertical column is equal to

$$u_0 = u/\eta , \tag{2}$$

where η is the air mass, and the lower limit of u_0 is around 0.1-0.2 μ. This is much better than is achieved in observations from the earth with large telescopes and Coudé spectrographs (the instrumental limit with respect to u_0 is condensed water [droplets] around 10μ of condensed water. During the measurement the optical axis of the instrument is kept parallel to itself [sic]. Before the AIS crosses the pericenter it enters the limb in the southern hemisphere and crosses the planet in a northward trajectory with a certain inclination with respect to the meridian (see Fig. 1 of [11]).

The data which has been obtained up to the present have been only partially processed. Below results are given which were obtained on the Mars-3 AIS. Its orbital period was around 12 days. The instrument was connected during the passes through the pericenter on 15 and 27 Dec 71, and 9 Jan, 3 Feb, 16 Feb, 28 Feb, and 12 Mar 72, and functioned normally throughout each session. The 12 Mar measurement session was not carried out with the usual schedule; the instruments were turned down after the crossing of the limb, and turned off before the crossing of the terminator -- therefore there was no zero-point and sensitivity control. However, these quantities were supplied from correlations between them and temperature which had been found in previous measurements.

The distribution of H_2O along the trajectory is shown in Fig. 2. The u_0 curve gives the content of H_2O in the vertical column. This quantity never exceeds 8 μ of condensed moisture ($u = 8 \times 10^{-4}$ $g \cdot cm^{-2}$), and in the region of the polar cap it falls to below 1 μ.

The brightness temperatures T_B measured by the ir radiometer of Mars-3 are also shown in Fig. 2, along with the photometric curve B in the continuous spectrum in the 1.38 μ region. At latitudes around 50° the subsatellite track entered the region of the northern polar cap; here the water vapor practically disappears. An analogous curve was published previously for the course of 28 Feb 72 [11].

In the series of 12 Mar 72 the H_2O content reached a level of 25 μ, whereas for all previous courses it had been less than 8 μ. Here ir brightness temperatures were also given, in certain cases, from measurements with an ir radiometer along the same trajectory [12]. The precision of measurement of the H_2O content in the vertical column is from ±0.3 to ±0.5 μ of condensed water.

In the courses of 15 Dec and 27 Dec a visible decrease in the H_2O occurred toward the equator. This is very likely explained by the fact that these measurements were made during dust storms; the scale of the dust clouds increases toward the equator, and at low latitudes the clouds have a greater weakening effect on the absorption bands.

In certain cases there is a tendency for the amount of H_2O /48
to be less above dark regions in comparison with neighboring continents; sometimes it is as little as half as much. No small regions ("oases") with elevated atmospheric moisture were observed. H_2O contents measured from December to February are unusually small, even for such a dry planet as Mars. Fig. 3 shows the comparison with results of water contents determined from earth observations in 1963-1965,

relative to the solar longitude L_s (L_s = 0 corresponds to the vernal equinox in the northern hemisphere). The earth-based determinations give 10-50 μ of condensed water; in certain cases only the upper limit was obtained. This scatter undoubtably reflects real variability of the water content of the Martian atmosphere.

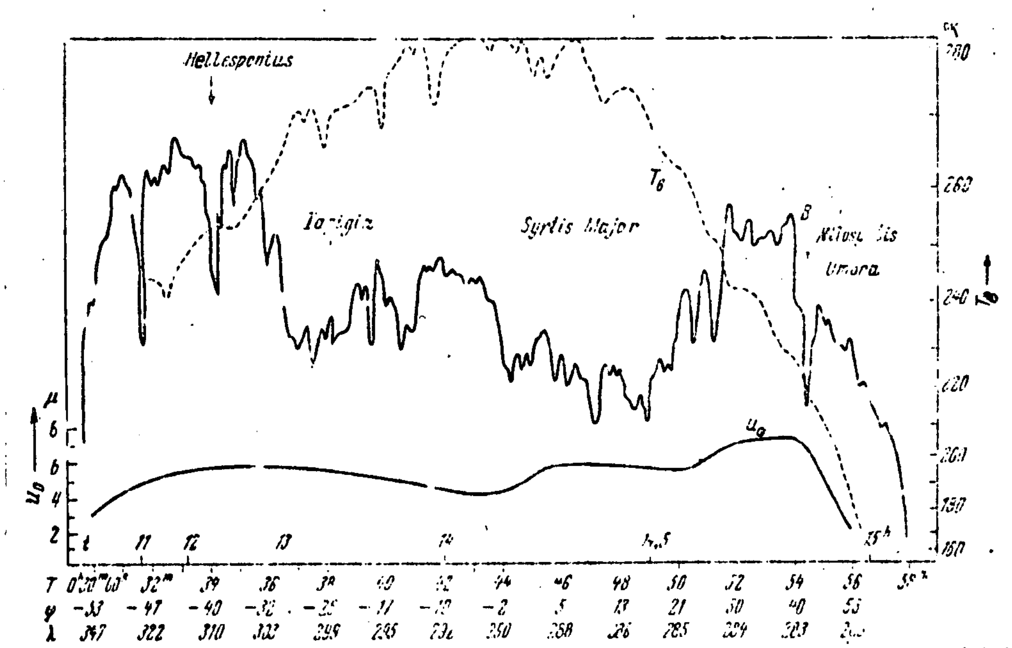

Fig. 2. Water content, photometric cross-section, and brightness temperature of the surface along the course of 16 Feb 72.
Abscissas: t = Mars local time;
T = Moscow time; φ = latitude;
λ = longitude of the subsatellite point

The infrared temperatures given in Fig. 2 refer to the surface, and do not permit any direct conclusions about the relative humidity. If an atmospheric temperature of around 200°K is assumed, then 10 μ of condensed water corresponds to a relative humidity of 3%. Saturation is reached only in the region of the northern polar cap, where the atmospheric temperature is substantially lower.

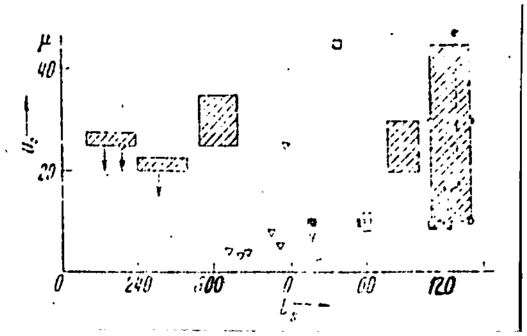

Fig. 3. Determination of water content from earth-based observations, and by Mars-3. The triangles are the maxima measured in each course of the Mars-3 AIS; the other points are earth-based observations [3].

Evidently the low moisture content in the atmosphere can explain the drop in the density of the hydrogen corona of Mars in the period of observation, compared to 1969, when it was measured by Mariners 6 and 7 [13].

Water content determinations from the measurements of Mariner 9 were published only in very fragmentary form, but what is known to us [9, 14] also indicates very low moisture in the Martian atmosphere during the period of observation.

In addition to the water content of the atmosphere, the IV-2 instrument gives detailed photometric profiles (Fig 2 B). The results will be published.

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